SVERIGES
LANTBRUKSUNIVERSITET

Decomposition of leaf and root litters from some coniferous and broad-leaved trees at sites located in different parts of Sweden.

Maj-Britt Johansson

Rapporter i skogsekologi och skoglig marklära Rapport nr 42
Reports in Forest Ecology and Forest Soils

Institutionen för skoglig marklära
Department of Forest Soils
Swedish University of Agricultural Sciences

ISSN 0348-3398
ISBN 91-576-1933-6

Tryck: Sveriges lantbruksuniversitet, Uppsala 1984

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1. ABSTRACT

The dry weight loss after one year of decomposing litter from different tree species was measured at 23 localities by using the litterbag technique. The sites, mostly containing two pure stands of different tree species (Norway spruce and Scots pine resp. or Norway spruce and birch resp.) or otherwise single stands, were located in different parts of Sweden. Leaf and root litter from Scots pine, Norway spruce, birch and lodge pole pine were incubated in their natural systems. A number of statistically significant differences between the litter decomposition rate constant (k_1) and site properties were obtained. Decomposition of Scots pine needle litter was significantly faster ($p<0.01$) at sites containing grass and herbs as ground vegetation than on sites with lichens as understory. Scots pine needles also decomposed faster ($p<0.05$) on sites where dwarf shrubs grew than on sites with lichens. A strong correlation ($p<0.001$) was also obtained between weight loss of Scots pine needles and the site's latitude. Norway spruce needles were found to decompose considerably slower than both Scots pine needles and birch leaves. A surprising similarity existed between the weight loss rate of Norway spruce needles regardless of the site's ground vegetation or location (latitude). Correlations were obtained neither between the decomposition rate of Norway spruce needles and roots and Scots pine roots and latitude nor ground vegetation.

2. INTRODUCTION

Different tree species produce needle and leaf litter of different shape and of different chemical composition. It has also been stated that condiderable variation in resistance to decay is found between the litters from different tree species. This has been shown in laboratory tests (Daubenmire & Prusso, 1963, Mikola, 1954, Broadfoot & Pierre, 1939), through incubation of different litters in a common stand (Mikola, 1954, 1960, Berg & Wessen, 1983, Berg & Staaf, 1980) and finally through weight loss studies of different litters incubated in their respective systems at a common site (Rosswall, Veum and Kärenlampi, 1975). It is generally considered that the difference in resistence to decay among litters is an effect of substrate quality which, together with moisture and temperature (Meentemeyer, 1978), are the main regulating factors in litter decomposition. The studies carried out by Broadfoot and Pierre (1939) and Berg and Staaf (1980) support this consideration. They found good correlations between the nutrient level of the litter and the initial weight loss rate.

As litter quality is only one of the main regular factors in the decomposition process, it appears reasonable to believe that the other factors, temperature and moisture, can be more rate determining than litter quality if the litter's resistance to decay is compared in natural systems. Large differences in local climate inside the stands seems to exist in stands of different tree species. At good sites, preferably in the south of Sweden, stands of Norway spruce usually contain very scanty field and bottom-vegetation and frequently no vegetation exists at all. The dark conditions existing in pure stands of Norway spruce not only affect the forest floor vegetation but probably also the temperature climate in the stand. The conditions existing in a nearby Scots pine stand differ widely from those described above. As mature Scots pines have a different morphology with branches only in the uppermost part of the tree and a Scots pine stand usually has a lower density (no. of trees/ha) the ground climate in these stands is very different. Here a luxuriant ground vegetation with herbs, grasses, dwarf shrubs and mosses often exists.

Very few decomposition studies have considered the decomposition rate of the litters after incubation in their respective systems.

The aim of the present study, which is part of an investigation into the net influence of different tree species on soil processes, was to investigate the decomposition rate of litters from different tree species, incubated in their own systems. This was done at about 20 sites, often containing two stands (both of the same age) of different tree species (Norway spruce/Scots pine or Norway spruce/birch), otherwise in single stands, by incubating the stand´s own litter in their natural systems. This report deals with weight losses of leaf and root litter from different tree species after 1 year´s incubation. The results obtained are evaluated for litter quality as well as for site properties.

3. MATERIALS AND METHODS

3.1 Litter preparation

Leaf and root litter were sampled from the stands at the studied sites in autumn 1978. By placing a tarpaulin on the ground and shaking the branches of the trees, the brown needles from the falling needle generation and yellow-brownish leaves were collected. Root litter was prepared in the following way: live roots of about 13 mm Ø were dug up and cut into 10 cm pieces.

Before weighing, the litter was air-dried at room temperature to about 5-8% moisture. Dry weight was determined (48 h, 85°C) and the largest difference in moisture was less than ±0.5% of the average (n=10).

3.2 Field incubations

The litter was incubated in litterbags made of terylene net measuring 10x10 cm. An amount of 1.5 g of leaf litter or a root piece of 10 cm length was enclosed in each bag. Bags with the following mesh sizes were used: Scots pine needles and roots: 1 mm, spruce needles: 0.5 mm and birch leaves >5 mm.

The litterbags containing leaf litter were placed on the litter (L) layer and those containing roots were placed between the humus layer and the mineral soil, in a measurement plot (1x1 m) in each of 25 blocks in a randomized block design in the different stands. The bags were fastened to the ground by 10-15 cm long metal pins.

The experiment was started in mid April 1979 in the stands located in South Sweden, during May in the stands located in the middle of Sweden and in June in the northern parts of the country. Samplings were made twice a year during a four-year period.

On each sampling occasion one litterbag from each of the 25 plots in each stand was collected. The litterbags were transported directly to the laboratory and cleaned of moss, lichen, grass and dwarf shrub remnants. After drying at 85^{0}C (48 h) they were weighed individually and then pooled to one sample for each set.

Calculations of individual weight loss values for the 25 litterbags and mean weight loss values for the 25 plots in each stand were then carried out. As the 1-year incubation time varied slightly between sites (not always 365 days) the exponential decomposition rate constants k_1 (Olson 1963) were also calculated. The k_1 values give a comparison between sites on an exact 1-year (365 days) basis.

3.3 Classification of ground vegetation type

At each site a description of the ground vegetation in the stands was carried out. Through an examination of the field and bottom layer in a circular sample plot with a radius of 10 m, the ground vegetation type according to Hägglund & Lundmark (1982) was determined. The ground vegetation type used is a development of the previous forest vegetation type (Hägglund & Lundmark, 1977). Strong correlation exists between the ground vegetation type of a site and its site index H100 (Lundmark, 1974).

The ground vegetation typ was determined in the stands on the same sample plot as the production determinations were carried out. Thus, the sample plot of 10x15 m where the decomposition studies were carried out does not always coincide with the sample plot where the ground vegetation type is determined.

4. SITE DESCRIPTIONS

4.1 Geographical location

The sites are listed in Table 1 ranging from south to north and are marked for approximate location (Fig. 1). As seen from the table and figure the sites are spread out well over the country from 56°26'N, 14°35'E to 66°22'N, 20°02'E.

4.2 Soils

The preliminary soil texture of the sites according to the A.S.T.M. system are listed in Table 1. Sites containing till deposits as well as sites covered with glaciofluvial and post-glacial water-transported sediments are represented in the investigation.

4.3 Vegetation

Stand Almost pure stands of Norway spruce, Scots pine or birch were studied. The sites usually contained two stands of different tree species, Norway spruce and Scots pine or Norway spruce and birch. Bottom- and field layer The ground vegetation was described according to the system of Hägglund and Lundmark (1982) in which the ground vegetation is classified in different ground vegetation types. A large range in variation exists according to the ground vegetation types represented at the sites. Stands with poor lichen types as well as those with tall herb types as ground vegetation are represented in the material (Table 1).

5. RESULTS AND DISCUSSION

5.1 Methodological aspects

Decomposition studies with local litters were carried out in stands of Scots pine, Norway spruce, lodge pole pine and birch. The decomposition rates of the litter incubated at sites containing more than one stand may be compared pairwise. As the stand´s own litter has been studied, litterbags with different mesh sizes were, unfortunately, used. The pine needles were incubated in litterbags of 1 mm mesh net. This mesh size has become something of a standard size not only for Swedish studies but also for studies carried out abroad. Larger mesh sizes probably cannot be used for pine needles because pieces of needles get lost through the meshes. Litterbags of the "standard" 1 mm mesh size cannot be used in decomposition studies of Norway spruce needles. In this case litterbags with a mesh size of about 0.5 mm were used to avoid losses of needles Before any comparisons between the decomposition rate of Scots pine and Norway spruce needles can be made, the influence of mesh size (0.5 mm and 1 mm) on decomposition rate must be investigated. With a view to elucidate this, Scots pine needles were incubated at 5 sites in litterbags with both 1 mm net and 0.5 mm net. The needles were degraded to the same extent both in one year, two years and three years (Johansson, to be published). The result obtained suggests no effect on decomposition rate of any changed moisture conditions inside the litterbags between mesh sizes 0.5 or 1 mm. Comparisons between the decomposition rates of Scots pine needles and Norway spruce needles, incubated in their respective systems, are made in this report as a consequence of the result obtained above.

The studies on decomposition of birch leaves (Table 2) were carried out in litterbags with a net of larger mesh, viz, about 5 mm. As leaves are used as food of different larvae and lumbricids the litter was incubated in the litterbag, which allowed access to these organisms. Comparisons between Norway spruce needles and birch leaves incubated in their respective system located close to each other, are more complex than those between Norway spruce needles and Scots pine needles. The litterbags used were very different and in this case we cannot exclude an effect of changed moisture conditions due to different mesh sizes. Another factor which may complicate the interpretation of decomposition data is leaching (Nykvist, 1963) which, in the case of birch leaves, gives rise to an initially high weight loss due to factors other than biological activity.

5.2 Decomposition as a function of litter quality

Spruce needles were degraded slower than both Scots pine needles and birch leaves (Table 2). A comparison between stands of Scots pine and Norway spruce located very close to each other showed that the needles from the latter were degraded at a significantly lower rate than Scots pine litter. The Scots pine needles lost 35-44 per cent in weight during one year whereas spruce needles lost 19-33 per cent during the same period. From only two sites, Tönnersjöheden and Garpenberg, were there weight loss values for birch and spruce needles incubated in their respective systems. The stands at these sites are located almost side by side. At Tönnersjöheden, birch litter in the first year lost 56.6 per cent of its weight (including leached material) whereas in the spruce forest the needles lost only 24.3 percent. Corresponding weight loss values at Garpenberg are 49.7 per cent and 25.9 per cent for birch leaves and spruce needles, respectively.

As litter decomposition is dependent on litter quality, among other factors such as temperature and moisture, the result obtained is analysed concerning the litter´s chemical composition. Any comparisons between different litters chemical composition ought to be done with caution as the nutrient level, for example, probably is site dependent. This has been found for the nitrogen content in green needles (see e.g., Tamm, 1964). With regard to this, comparisons may be carried out only between stands located at a main site.

Taking this into consideration, it was found that Norway spruce needles and birch leaves always had higher levels of nutrients and lignin than Scots pine needles (Johansson, to be published). Birch leaves also had higher levels of solubles than both Scots pine needles (Berg and Wessen, 1984, Johansson, 1982) and Norway spruce needles (Johansson, to be published).

Both Broadfoot and Pierre (1939) and Berg and Staaf (1980) found good correlations between the nutrient level of the litter and the initial weight loss rate. Results from the litterbag study carried out in this report support their findings only partly. Beside the birch leaves, where high levels of solubles can be responsible for their high initial weight loss rate, the obtained result is not in accordance with the theory of substrate quality. The higher levels of nutrients had by the spruce needles compared to the pine needles, did not result in a higher weight loss rate of the spruce needles in this study. In addition to the higher levels of nutrients, Norway spruce needles had also higher levels of lignin, a factor which should retard decomposition but not until the later stages of the process (Berg and Staaf, 1980).

5.3 Decomposition as a function of ground vegetation type

The weight loss values obtained for 1-year's incubation of Scots pine needles, Norway spruce needles and birch leaves were compared to the ground vegetation types at the sites. Table 4 shows average weight loss values and average weight loss rate constants. A strong influence of ground vegetation on the decomposition rate of Scots pine needle litter was found. For Scots pine needles the average 1-year weight loss values for lichen types, dwarf shrub types and grass + herb types were 20.42, 30.38 and 37.90 per cent, respectively. The average weight loss values for the lichen types and the grass + herb types were significantly different ($p<0.01$), as well as those for the dwarf shrub types and lichen types ($p<0.05$). The results obtained indicate that there are important differences in the 1-year decomposition rates between these two systems. Between the dwarf shrub types and the grass + herb types no significant difference existed. Despite this, significant differences in weight losses of Scots pine needles were found between all of these three ground vegetation types in a study carried out at the Manjärv, N., Manjärv, S. and Manjärv, lastrea sites. The sites were located very close to each other - all of them within a circular area with less than 50 m radius. The three Scots pine stands had different ground vegetation types, reflecting different nutrient status. The lowest weight loss value (19.8%) was seen in the nutrient-poor stand where the ground vegetation consisted of lichens. A weight loss value of 25.9 per cent was obtained in the stand with V. vitis idaea as understory and 30.7 per cent in the most nutrient-rich stand where the ground vegetation was of herb type.

Corresponding average 1-year weight loss values of Norway spruce needles did not show any significant difference between different types of ground vegetation (Table 4). A surprising similarity exists between the decomposition rate of Norway spruce needles in the different ground vegetation types, during the first year of incubation. The initial decomposition rate of Norway spruce needles is the same in Norway spruce stands with the ground vegetation containing herbs and grasses, as in stands containing no field layer vegetation at all.

For birch leaves the number of sites with different ground vegetation types was too small and no calculations of average weight losses according to different ground vegetation types could be carried out.

5.4 Decomposition as a function of geographical location

Weight loss values for 1-year incubation of Scots pine needles, Norway spruce needles and birch leaves at different sites, located from south to north in Sweden, were obtained. When the weight loss values were compared to the latitudes of the sites, a correlation was obtained between the values for first year weight losses for Scots pine needles and latitude ($R=0,831$ $p<0.001$) (Fig. 2).

The result indicates a lower decomposition rate when the latitude is increased from south to north. This indication was also found by Mikola (1960). He found a decreasing decomposition rate of Scots pine needles and birch leaves from south to north in Finland with the litters incubated in Scots pine stands. No correlation was obtained between the values for first year weight losses for Norway spruce needles or birch leaves and latitude.

Also here a strong influence of the ground vegetation on the decomposition rate of Scots pine needle litter was found. If the k_1-values for Scots pine needle were divided into two groups according to the site's ground vegetation type before being plotted against latitude, an interesting result was obtained. The two ground vegetation groups used were 1) lichen types and 2) herb + grass + dwarf shrub types. As seen from Fig. 2, two distinct lines (three lines if the line for all vegetation types together is taken into account) are obtained at different levels. (Lichen types: $K_1=-0.0226$ lat $+ 1.683$ $R=0.879$ $P<0.05$, grass + herb + dwarf shrub types; $K_1=0.0292$ lat $+ 2.210$ $R=0.872$ $p<0.001$). Within each vegetation type it is seen that decomposition rate varies with latitude. The highest decomposition rate in this comparison is found in forests with herbs + grasses + dwarf shrubs whereas in stands containing lichens as ground vegetation, the decomposition rate of Scots pine needles was lowest.

The two distinct lines in Fig. 2 both have different slopes, which means that the dependency of latitude on the decomposition rate varies between the two vegetation types. It is most marked in stands containing herb + grass + dwarf shrub types as ground vegation whereas in stands of lichen types, the dependency of latitude on the weight loss of Scots pine needles is of somewhat less importance. Consequently, the influence of ground vegetation type on the weight loss of Scots pine needles decreases from the south to the north in Sweden. It appears that the severe climate in northern Sweden is more rate determining than ground vegetation type on the 1-year weight loss rate of Scots pine needles.

No correlation was obtained between the weight losses during the first year of spruce needles and birch leaves, and latitude.

5.5 Decomposition studies with root litter

In Table 3 the results from the decomposition studies with Scots pine, Norway spruce, lodge pole pine and birch root litter are listed. When comparing stands of different tree species at the same main site, it appears that birch roots are degraded slower than roots of Norway spruce during the first year of incubation. The 1-year weight loss value for birch roots at the Tönnersjöheden site is extremely low, only 17.0 per cent, whereas in the nearby Norway spruce stand the roots lost 36.4 per cent in weight during the same period. If the root degradation in Scots pine stands and Norway spruce stands are compared in the same manner as above, no clear tendencies are seen. However, it appears that Scots pine roots are degraded more than Norway spruce roots during the first year of incubation. At three of the compared sites (a total of 9), opposite results were obtained.

If the weight loss values obtained for 1-year's incubation of Scots pine and Norway spruce roots are compared to the site's ground vegetation types, no influence of ground vegetation type on root decomposition rate was found. The average weight losses and average weight loss rate constants given in Table 4 for the different ground vegetation types are not significantly different. No comparisons between vegetation and root degradation in stands of birch and lodge pole pine were carried out as there were too few sites with different ground vegetation types. Comparison of the degradation rate of the roots from the different tree species and the site's latitudes revealed no correlations. The Scots pine roots incubated at the Hökensås site, which is located at latitude 58°N, did not differ in weight loss rate (30.1 per cent) from those incubated at the Harads site (29.7 per cent) at latitude 66°N. The big difference in weight loss of Scots pine needle litter between these sites (Hökensås 30.0 per cent, Harads 11.1 per cent) was thus not reflected in the root litter. The root litter was incubated between the mineral soil and the humus layer. Thus, it might be reasonable to consider factors which regulate the temperature and moisture conditions at this level in the soil, e.g., the thickness of the humus layer, as being responsible for the result obtained.

6. CONCLUDING REMARKS

In this study, 1-year decomposition rates of litter from the tree species Norway spruce, Scots pine, lodge pole pine and birch incubated in their respective systems were examined. The 23 sites, often containing two pure stands of different tree species (Norway spruce and Scots pine resp. or Norway spruce and birch resp.) were located all over the country. A number of statistically significant differences between the litter's weight loss rate (k_1) and site properties occurred. Decomposition of Scots pine needle litter was significantly faster ($p<0.01$) at sites containing grass and herbs as ground vegetation than on sites with lichens as understory. Scots pine needles also decomposed significantly faster ($p<0.05$) on sites where dwarf shrubs grew than on sites with lichen as ground vegetation. It appears that Mikola (1954), who recommended an admixture of broad leaved species with coniferous to aid litter decomposition, thereby promoting the development of an herbaceous ground flora, was aware of this condition. Scots pine needles are also decomposed faster in southern parts of Sweden than in northern. A strong correlation ($p<0.001$) was obtained between the 1-year weight loss value and the site's latitude.

Norway spruce needles were found to decompose at a considerably lower rate than both Scots pine needles and birch leaves. Levels of nutrients which, according to Broadfoot and Pierce (1939) as well as Berg and Staaf (1980), are correlated to the initial weight loss rate of the litter, could not explain the result observed in this study. The explanation appears to be found among the remaining regular factors for litter decomposition, temperature and moisture, as litter quality (nutrient levels) is omitted. It might be expected that temperature and moisture regimes which were constant in the studies where correlations between content of nutrients and weight losses were obtained, varied considerably between the soil surfaces in Scots pine and Norway spruce stands. The differences ought to be largest between stands with different understory, as the ground vegetation - indicating the site's quality as well as light climate at soil surface - probably also gives rise to different moisture conditions. The large difference in weight loss of needles between pine stands with luxuriant ground vegetation and Norway spruce stands without ground vegetation supports this consideration.

In contrast to Scots pine needles, a surprising similarity existed between the decomposition rates of Norway spruce needles, regardless of the stand's ground vegetation types or the site's location. Thus, it might be reasonable to believe that the decomposition rate of Norway spruce needles is more influenced by soil surface temperature. As Norway spruce stands are often darker and denser than Scots pine stands, a lower temperature ought to exist at the ground. The thinner snow-covers in winter probably also gives rise to other temperature conditions at the soil surface. It was not possible here to establish whether the low weight loss rate of Norway spruce needles during the first year was caused by low soil surface temperatures in general and further investigations into temperature and moisture regimes in stands of different tree species are needed. Furthermore, elaborate chemical analyses of spruce needle litter are also needed as it cannot be excluded that the low weight loss rate is an effect of toxic substances in the litter.

As regards decomposition rates of root litter, it seems that birch roots are decomposed slower than Norway spruce roots, which seems to decompose slower than Scots pine roots. The results refer to comparisons between stands located at main sites. No correlations between the rate of the root weight loss and ground vegetation type of the stands or the site's locality (latitude) were found. As the roots were incubated between the mineral soil and the humus layer, the result obtained might be an effect of, e.g., the thickness of the humus layers.

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Table 1. Data of the sites referred to in the paper. The preliminary data of ground vegetation type and soil (texture) are given by Lundmark (pers. comm.)

Site name	Lat/long	Altitude m.a.s.l.	Tree species	Ground vegetation type according to Hägglund & Lundmark (1982)	Soil (texture) according to A.S.T.M.
Skällarim	66°32'N; 20°11'E	280	Scots pine	Vaccinium myrtillus type	sandy till
Ätnakobbo	66o22'N; 20°02'E	405	Norway spruce	Vaccinium myrtillus type	sandy till
Harads	66°08'N; 20°53'E	58	Scots pine	Lichen type	fine sand
Brännberg	65°47'N; 20°12'E	120	Scots pine	Vaccinium myrtillus type	sandy till
Manjärv N.	65°47'N; 20°37'E	135	Scots pine	Lichen-rich type	fine sand
Manjärv S.	65°47'N; 20°37'E	135	Scots pine	Vaccinium vitis idaea type (->V. myrtillus type)	silt
Manjärv lastrea	65°47'N; 20°37'E	135	Scots pine	Low herbs with dwarf-shrubs	silty coarse clay
Fäbotjälen	64°40'N; 19°52'E	295	Scots pine	Vaccinium myrtillus type	sandy till
Dorotea	64°18'N; 16°20'E	330	Lodge pole pine	Vaccinium myrtillus type	not determined
Svartberget	64°15'N; 19°46'E	230	Norway spruce	Vaccinium myrtillus type	sandy till
Avalund	64°15'N: 19°08'E	275	1. Scots pine	Lichen-rich type	sandy till
			2. Birch mixed with Scots pine	Vaccinium myrtillus type	sandy till
Åheden-lav	64°14'N; 19°47'E	175	Scots pine	Lichen type	fine sand
Åheden-lavrik	64°14'N; 19°47'E	175	Scots pine	Lichen-rich type	fine sand
Åheden-lingon	64°14'N; 19°47'E	175	Scots pine	Vaccinium vitis idaea type	fine sand
Frösön	63°13'N; 14°28'E	325	1. Scots pine	Vaccinium myrtillus type	clayey till (parent material: shale)
			2. Norway spruce	Vaccinium myrtillus type	clayey till (parent material: shale)
Garpenberg	60°16'N; 16°15'E	185	1. Norway spruce	Vaccinium myrtillus type	gravelly sandy till
			2. Birch	Low herbs type	gravelly sandy till
Månkarbo	60°14'N; 17°28'E	40	1. Norway spruce	Low herbs type	not determined
			2. Birch	Low herbs type	not determined

Sid. 2 Tab. 1

Site name	Lat/long	Altitude m.a.s.l.	Tree species	Ground vegetation type according to Hägglund & Lundmark (1977)	Soil (texture) according to A.S.T.M.
Tomta	59°49'N; 16°33'E	63	1. Scots pine	Vaccinium myrtillus type	silt
			2. Norway spruce	Ground without field layer	silty-fine sand
Kungs-Husby	59°31'N; 17°16'E	30	1. Scots pine	Vaccinium myrtillus type	fine clay
			2. Norway spruce	Ground without field layer	fine clay
Dimbo	59°07'N; 15°44'E	70	1. Scots pine	Low herbs type	fine sand - medium sand
			2. Norway spruce	Low herbs type	fine sand - medium sand
Grensholm	58°33'N; 15°51E	58	1. Scots pine	Tall herbs type	boulder clay
			2. Norway spruce	Tall herbs type	boulder clay
Remningstorp	58°28'N; 13°39'E	128	1. Scots pine	grass type	gravelly-sandy till
			2. Norway spruce	Low herbs type	gravelly-sandy till
Tveten	58°06'N; 13°17'E	170	1. Scots pine	Vaccinium myrtillus type	sandy till
			2. Norway spruce	Ground without field layer	sandy till
Hökensås	58°04'N; 14°08'E	245	Scots pine	Lichen type	fine sand - medium sand
Tönnersjöheden	56°42'N; 13°05'E	80	1. Norway spruce	Ground without field layer	sandy till
			2. Birch	Low herbs type	sandy till
Mästocka	56°36'N; 13°15'E	135	1. Scots pine	Vaccinium myrtillus type	sandy till
			2. Norway spruce	Ground without field layer	sandy till
Farabol	56°26'N; 14°35'E	140	Norway spruce	Grass type	sandy till

Table 2. Weight loss rates for local needle and leaf litter at the studied sites. Standard deviation within paranthesis.

Site	First year weight loss (o/o)	Rate Constant K_1	Number of replicates per sampling
Scots pine - V-myrtillus type			
Mästocka	42.2 (3.5)	0.55	25
Tveten	36.3 (2.4)	0.45	25
Kungs-Husby	38.1 (3.9)	0,48	25
Tomta	36.9 (2.8)	0,46	25
Frösön	36,4 (2,4)	0,45	25
Fäbotjälen	25.4 (1.9)	0.31	25
Brännberg	22.2 (2.2)	0.26	25
Skällarim	17.9 (2.3)	0.20	25
Scots pine - low herbs type			
Dimbo	43.7 (3.7)	0.58	25
Manjärv lastrea	30.7 (4.3)	0.37	25
Scots pine - tall herbs type			
Grensholm	42.0 (4.3)	0.54	25
Scots pine - lichen type			
Hökensås	30.0 (1.6)	0.35	25
Åheden lav	20.9 (1.9)	0.25	25
Harads	11.1 (1.4)	0.12	25
Scots pine-lichen-rich type			
Avalund	21.1 (2.5)	0.26	25
Åhenden lavrik	19.6 (1.9)	0.23	25
Manjärv N	19.8 (2.2)	0.22	25
Scots pine - grass type			
Rämningstorp	35.2 (2.4)	0.44	25

Site	First year weight loss (o/o)	Rate Constant K_1	Number of replicates per sampling
Scots pine-V. vitis idaea type			
Manjärv S.	25.9 (3.5)	0.30	25
Åheden lingon	22.5 (1.8)	0.27	25
Lodge pole pine- V. myrtillus type			
Dorotea	34.5 (3.0)	0.43	25
Norway spruce - V. myrtillus type			
Ätnakobbo	20.1 (3.6)	0.23	25
Svartberget	26.9 (3.2)	0.30	25
Frösön	32.8 (3.6)	0.40	25
Garpenberg	25.9 (2.0)	0.30	25
Norway spruce - grass type			
Farabol	25.2 (2.5)	0.29	25
Norway spruce - low herbs type			
Remningstorp	30.3 (3.5)	0.36	25
Dimbo	26.8 (2.2)	0.32	25
Månkarbo	27.8 (2.2)	0.32	25
Norway spruce - tall herbs type			
Grensholm	19.3 (1.1)	0.21	24
Norway spruce - ground without field layer			
Mästocka	28.8 (1.7)	0.34	25
Tönnersjöheden	24.3 (1.5)	0.27	25
Tveten	27.7 (2.2)	0.32	25
Kungs-Husby	26.9 (1.8)	0.31	25
Tomta	25.6 (3.3)	0.29	25
Birch - low herbs type			
Garpenberg	49.7 (9.3)	0.68	24
Månkarbo	79.7 (8.3)	1.59	25
Tönnersjöheden	56.6 (11.5)	0.82	25
Birch mixed with Scots pine - V. myrtillus type			
Avalund	28.2 (2.7)	0.36	24

Table 3. Weight loss rates for local root litter incubated for 1-year between the humus layer and mineral soil at some sites. The root litter consists of root pieces of 10 cm length and 1-3 mm Ø.

Site	First year weight loss (o/o)	Rate Constant K_1	Number of replicates per sampling
Scots pine - V. myrtillus type			
Mästocka	36.4	0.45	25
Tveten	35.1	0.43	24
Kungs-Husby	34.2	0.42	24
Tomta	32.4	0.39	25
Frösön	32.6	0.39	25
Skällarim	19.7	0.22	25
Scots pine - low herbs type			
Dimbo	37.0	0.47	25
Manjärv lastrea	33.5	0.41	25
Scots pine - tall herbs type			
Grensholm	39.2	0.49	24
Scots pine-lichen type			
Hökensås	30.1	0.36	25
Harads	29.7	0.36	25
Scots pine - lichen-rich type			
Manjärv N.	35.5	0.44	24
Scots pine-grass type			
Remningstorp	40.8	0.53	25
Scots pine - V. vitis idaea type			
Manjärv S.	33.1	0.40	25
Lodge pole pine - V. myrtillus type			
Dorotea	35.3	0.44	25
Norway spruce - V. myrtillus type			
Ätnakobbo	27.4	0.32	25
Frösön	30.2	0.36	25
Garpenberg	30.4	0.36	25

Site	First year weight loss (o/o)	Rate Constant K_1	Number of replicates per sampling
Norway spruce - grass type			
Farabol	29.3	0,35	24
Norway spruce - low herbs type			
Remningstorp	38.3	0.48	25
Dimbo	31.3	0.38	25
Norway spruce - tall herbs type			
Grensholm	39.7	0.50	24
Norway spruce - ground without field layer			
Mästocka	32.0	0.38	25
Tönnersjöheden	36.4	0.45	25
Tveten	29.0	0.34	25
Kungs-Husby	35.1	0.43	25
Tomta	34.7	0.42	25
Birch-low herbs type			
Garpenberg	26.8	0.31	25
Tönnersjöheden	17.0	0.18	25

Table 4. Average weight loss values and rate constants for needle and root litter of Scots pine, Norway spruce and birch at sites with different ground vegetation types.

Litter	Ground vegetation type	Number of sites	Average weight loss w.l. (o/o)	S.E.	Average rate constant K_1	S.E.
Scots pine needles	grass + herb types	4	37.90	3.02	0.48	0.05
" " "	dwarf shrub types	10	30.38	2.67	0.37	0.04
" " "	lichen types	6	20.42	2.45	0.24	0.03
Scots pine roots	grass + herb types	4	37.60	1.57	0.47	0.05
" " "	dwarf shrub types	7	31.93	2.11	0.39	0.03
" " "	lichen types	3	31.77	1.87	0.38	0.03
Norway spruce needles	grass + herb types	5	25.88	1.84	0.30	0.02
" "	ground without field layer	5	26.66	0.79	0.31	0.01
" "	dwarf shrub types	4	26.43	2.60	0.31	0.04
Norway spruce roots	grass + herb types	4	34.58	2.51	0.43	0.04
	ground without field layer	5	33.44	1.32	0.40	0.02
	dwarf shrub types	3	29.33	0.97	0.35	0.01

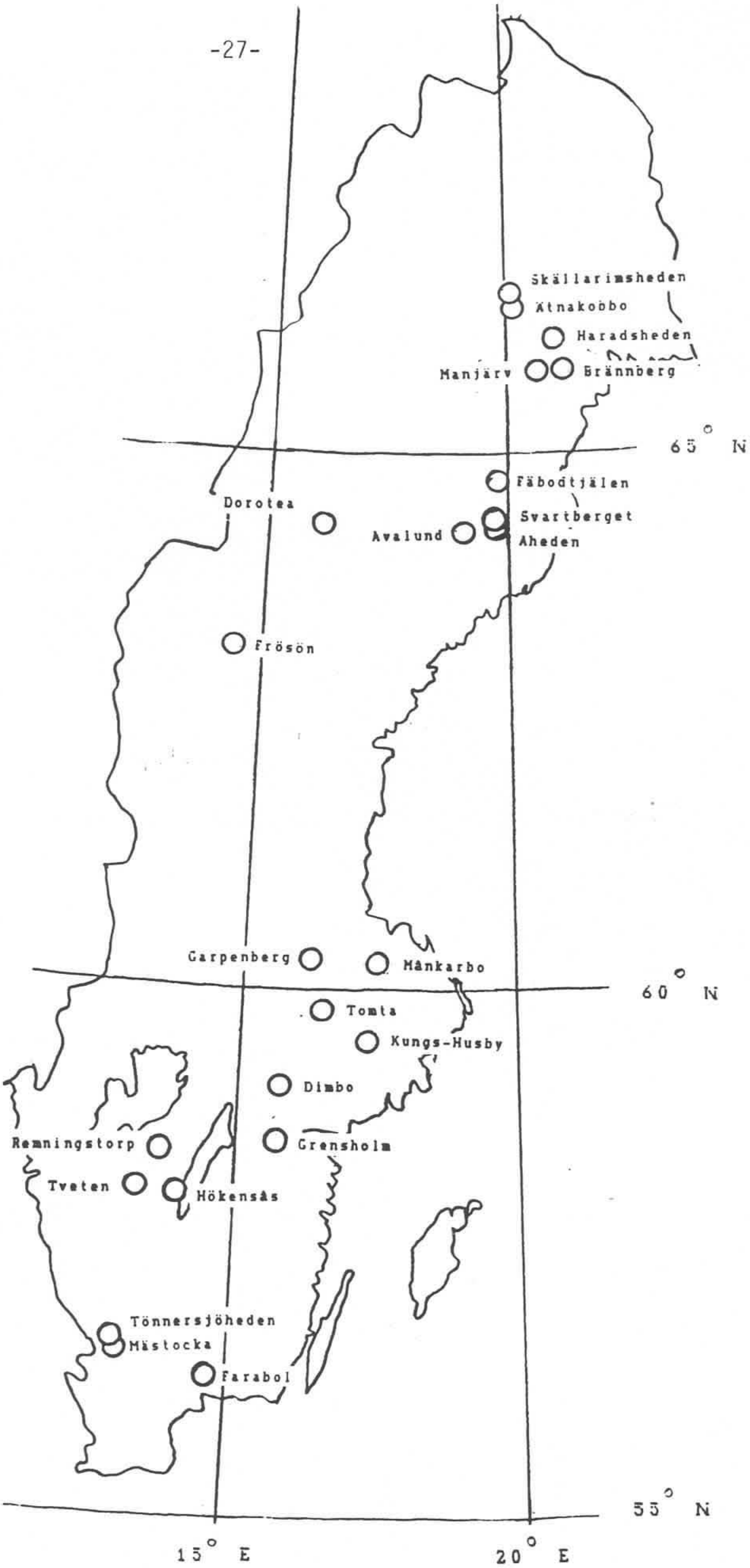

Fig. 1. Map of Sweden given the approximate locations of sites with decomposition studies referred to in this report

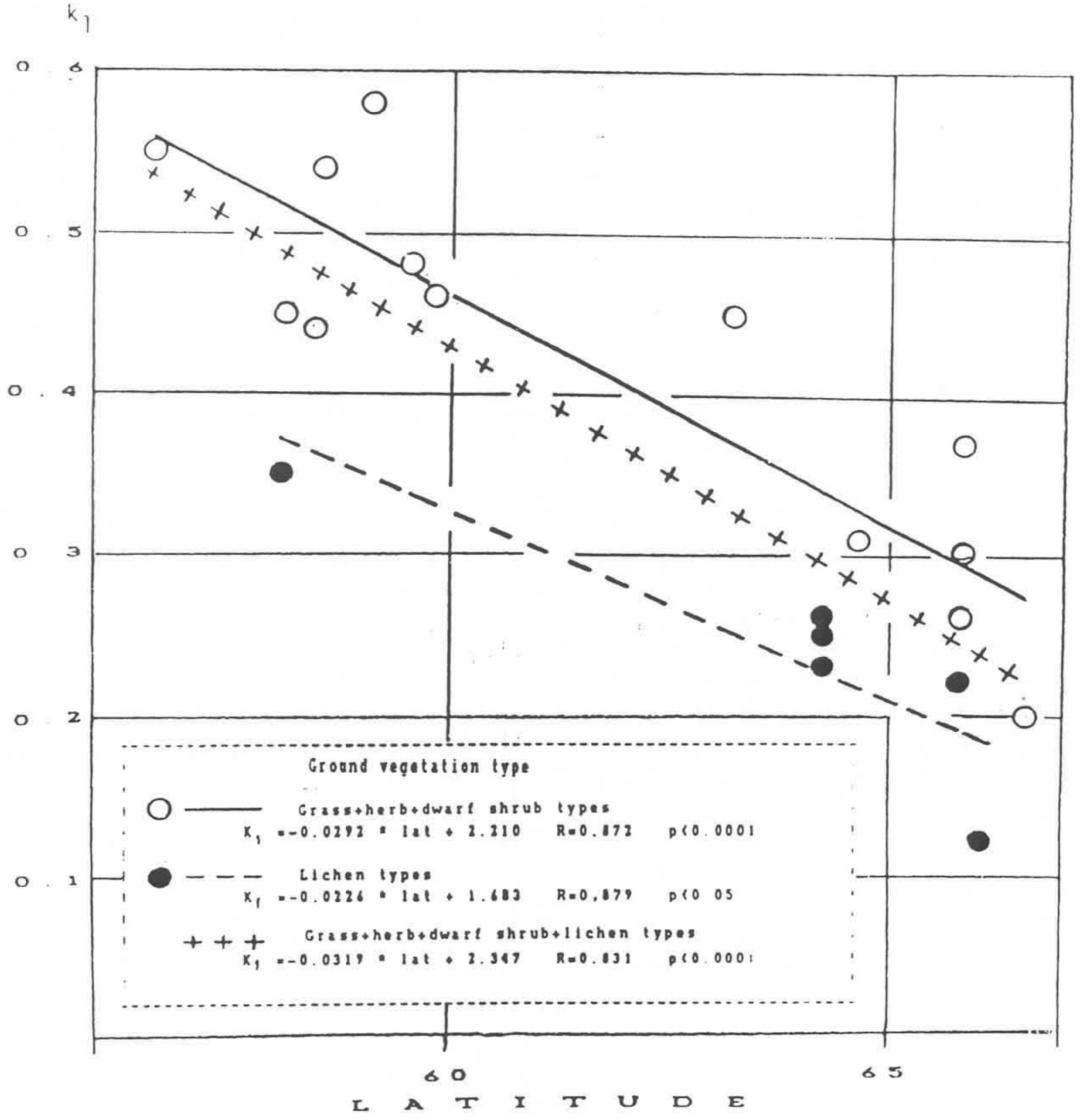

Fig. 2. Decomposition rate constants for first year weight loss of Scots pine needles plotted versus latitude.

○	Scots pine stands with ground vegetation types; grass + herb + dwarf shrub types
———	The regression line drawn
●	Scots pine stands with the ground vegetation type; lichen type
— — —	the regression line
+ + +	The regression line for Scots pine stands with ground vegetation types; grass + herb + dwarf shrub + lichen types